

Rec'd PCTOTO 07 JAN 2005

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



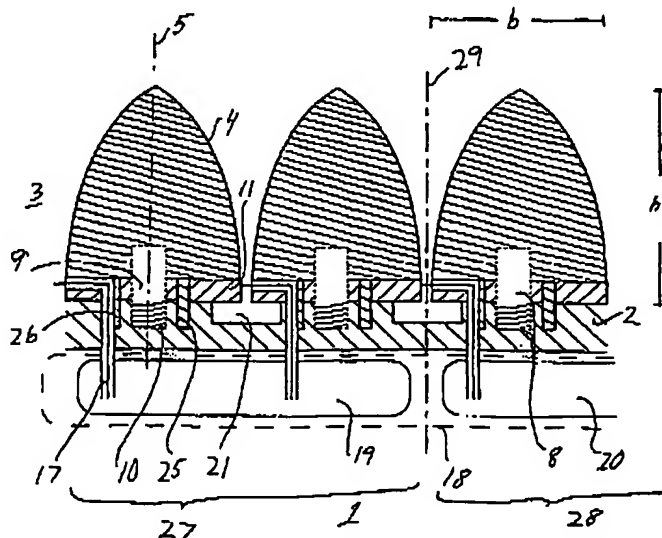
(43) International Publication Date
15 January 2004 (15.01.2004)

PCT

(10) International Publication Number
WO 2004/006388 A1

- (51) International Patent Classification⁷: **H01Q 21/06**, (81) Designated States (*national*): AE, AG, AL, AM, AI, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (21) International Application Number: PCT/SE2003/001098
- (22) International Filing Date: 25 June 2003 (25.06.2003)
- (25) Filing Language: Swedish
- (26) Publication Language: English
- (30) Priority Data: 0202123-6 8 July 2002 (08.07.2002) SE
- (71) Applicant (*for all designated States except US*): SAAB AB [SE/SE]; S-581 88 Linköping (SE).
- (72) Inventor; and
- (75) Inventor/Applicant (*for US only*): **HOLTER, Henrik** [SE/SE]; Söndagsvägen 34, S-123 60 Farsta (SE).
- (74) Agent: **FORSBERG, Carl-Göran**; Saab Bofors Support AB, Patents and Trademarks, S-691 80 Karlskoga (SE).
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published: — with international search report
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: ELECTRICALLY CONTROLLED BROADBAND GROUP ANTENNA, ANTENNA ELEMENT SUITABLE FOR INCORPORATION IN SUCH A GROUP ANTENNA, AND ANTENNA MODULE COMPRISING SEVERAL ANTENNA ELEMENTS



(57) Abstract: The invention relates to an electrically controlled group antenna (1), an antenna element (3) suitable for incorporation in such a group antenna, and antenna module comprising several such antenna elements. According to the invention, the antenna elements comprise a rotationally-symmetrical body (4) tapering towards one end of the body. The rotationally-symmetrical body is provided with a metallic casing surface. Several antenna elements (3) are arranged separately on a common earth plane (2). By means of the invention, a broadband group antenna is achieved that, among other things, is simple in design and is easy to manufacture and repair.

BEST AVAILABLE COPY

WO 2004/006388 A1

WO 2004/006388

3/PRTS

10/520462
DT15 Rec'd PCT/PTO 07 JAN 2005
PCT/SE2003/001098

1

Case 3930

Electrically controlled broadband group antenna,
antenna element suitable for incorporation in such a
5 group antenna, and antenna module comprising several
antenna elements

The present invention relates to an electrically
controlled broadband group antenna comprising a
10 plurality of antenna elements arranged in a common
plane and connected to a feeder unit. The invention
also relates to an antenna element suitable for
incorporation in an electrically controlled broadband
group antenna, the antenna element comprising a
15 rotationally-symmetrical body tapering towards one end.
In addition, the invention relates to an antenna module
with a plurality of such antenna elements. These group
antennas preferably work with linear polarization or
two orthogonal polarizations.

20 Electrically controlled broadband group antennas with
an instantaneous bandwidth larger than one octave are a
very important component in, among other things,
military telecommunication systems and multifunction
25 radar. There are currently only a few broadband antenna
elements that are suitable for electrically controlled
broadband group antennas. These antenna elements have a
plurality of disadvantages.

30 A known type of broadband group antenna uses antenna
elements that have the name "Tapered Slot". See, in
connection with this, IEEE Transactions on Antennas and
Propagation, volume 48, no. 11, November 2000, pages
1707-1718, Experimental Results of 144-Element Dual-
35 polarized Endfire Tapered-Slot Phased Arrays. In
general, for known electrically controlled broadband
group antennas, it is the case that the antenna
elements are complicated and their production is

WO 2004/006388

PCT/SE2003/001098

2

difficult and therefore expensive. This applies in particular for group antennas with two orthogonal polarizations. In addition, it is often difficult to connect the antenna elements to an underlying microwave unit.

With regard to group antennas with "Tapered Slot" antenna elements, we can mention in particular difficulties in achieving electrical contact between adjacent antenna elements, which is important for the electrical function. This applies, in particular, for high frequencies, as the element distance is small. For example, the element distance is only approximately 8.5 mm at a frequency of 18 GHz. Another difficulty is in connecting the antenna elements to an underlying lobe-shaping network or to underlying microwave units. In addition, there is the danger that electromagnetic resonances will arise in the antenna elements. These resonances can considerably impair the electrical characteristics of the antenna elements.

The object of the present invention is to achieve a group antenna and antenna elements that do not have the above disadvantages of known broadband group antennas. The object of the invention is achieved by means of a group antenna characterized in that each antenna element comprises a rotationally-symmetrical body arranged on an earth plane that is common to several antenna elements, with the axis of rotation of the body essentially perpendicular to the earth plane, which body, at the end furthest away from the earth plane, is shaped so that it tapers inwards with increasing distance from the earth plane and is provided with a metallic casing surface. Antenna elements suitable for incorporation in the group antenna are characterized in that the rotationally-symmetrical body is provided with a metallic casing surface.

WO 2004/006388

PCT/SE2003/001098

3

By means of the invention, a group antenna and antenna elements are achieved that are simple and cheap to produce. The installation of the antenna elements is simple and the adjacent antenna elements do not need to be welded together. The antenna elements consist of metal. In this way, the problems are avoided that are associated with dielectric substrates that are normally used in group antennas. Problems that are associated with dielectric substrates include losses, surface waves and resonances.

According to an advantageous embodiment, the earth plane of the group antenna is provided with recesses in the forms of slots that separate the antenna elements from each other and function electrically as open circuits. By means of the introduction of these slots in the earth plane, separation of the antenna elements has been achieved in a simple way, while at the same time the production of the slots only requires simple manufacturing technology and can be carried out, for example, by milling.

According to another advantageous embodiment of the group antenna according to the invention, the antenna elements are connected to the earth plane by means of a connection that can be broken, such as a screw connection. The antenna elements are characterized in that the other end of the body comprises means for attaching the body in such a way that it can be removed, and the means for attaching the body in such a way that it can be removed comprise, according to one embodiment, one part of a screw connection. The embodiment allows the antenna elements to be removed easily, which facilitates the replacement of defective antenna elements. Instead of scrapping a whole module of antenna elements, in the most favourable cases it is sufficient to unscrew and replace a single antenna element. As a result of the antenna element's

WO 2004/006388

PCT/SE2003/001098

4

symmetrical shape, the installation is made easier, as the antenna element can be screwed on in any rotational position.

- 5 According to yet another advantageous embodiment, a spacing sleeve is incorporated in each antenna element at the transition between the rotationally-symmetrical body and the earth plane. The spacing sleeve is suitably provided with at least one cable bush with a
- 10 first opening aligned in the radial direction of the spacing sleeve and a second opening aligned parallel with the axis of symmetry of the body and the sleeve. The incorporation of a spacing sleeve facilitates the attachment of the antenna elements to a lobe-shaping
- 15 network or microwave units lying under the earth plane. At the same time as the rotationally-symmetrical body of the antenna element is installed on the earth plane by means of a rotational movement, the cables incorporated and the spacing sleeve can be held fixed
- 20 relative to the earth plane.

- According to yet another advantageous embodiment, the earth plane is provided with two cable bushes for each antenna element, which are each allocated a double-
- 25 conductor, for example a coaxial cable, one conductor of which is attached to the antenna element and the other conductor of which is attached to an adjacent antenna element. The arrangement of cable bushes and the method of attaching the cables gives the group
- 30 antenna a logical construction and contributes to the simple attachment of the antenna to a feeder unit, such as a number of microwave units. The antenna according to the invention makes possible a close connection to microwave units and, according to an embodiment, the
- 35 feeder unit comprises one or more microwave units that form the antenna elements' common earth plane. By this means, power losses that arise in coaxial contacts and connection contacts are reduced, while at the same time

WO 2004/006388

PCT/SE2003/001098

5

the costs of coaxial contacts and coaxial cables disappear or are considerably reduced. In addition, a close connection to the microwave units saves space.

- 5 The antenna elements can be placed in a number of different grid configurations. Two attractive grid configurations in this connection can be the rectangular grid or the triangular grid.
- 10 According to a suitable dimensioning of the group antenna, two adjacent antenna elements are arranged with a distance between centres of essentially half a wavelength for the highest working frequency of the group antenna. This gives the group antenna an optimal
- 15 compact form without making the antenna more complex in its design.

The rotationally-symmetrical body of the antenna element can be given a number of different forms, such

20 as for example a circular paraboloid or a conical shape.

According to one embodiment, the rotationally-symmetrical body of the antenna element consists

25 principally of aluminium. The choice of aluminium as conductor gives the antenna element a low weight. Another embodiment of the antenna element according to the invention that keeps down the weight is to make the rotationally-symmetrical body hollow.

30

A stable and easily manufactured antenna element according to the invention is characterized in that the rotationally-symmetrical body consists of an homogenous metallic material. The antenna element can be

35 manufactured by turning and the homogeneity contributes to the stability of the antenna element.

WO 2004/006388

PCT/SE2003/001098

6

A group antenna according to the invention can be constructed of antenna modules, with each module comprising a plurality of antenna elements.

- 5 The invention will be described below with reference to the attached drawings in which:

Figure 1 shows schematically according to the section 1A-1A in Figure 2 a sectioned side view of a part of a
10 group antenna according to an embodiment.

Figure 2 shows a schematic top view of an embodiment of a group antenna according to the invention.

- 15 Figures 3a - 3c show in section through the centre of rotation three different examples of embodiments of a rotationally-symmetrical body comprised in an antenna element according to the invention.

- 20 Figure 4 shows in top view an example of a spacing sleeve that can be incorporated in the antenna element according to the invention.

The group antenna 1 shown in Figures 1 and 2 comprises
25 an earth plane or an earth plate 2 on which the antenna elements 3 are arranged. The antenna elements comprise a rotationally-symmetrical body 4 with an axis of symmetry 5. The ratio between the height h and the breadth b of an incorporated antenna element can vary,
30 but lies preferably within a range between the ratio 1:1 and the ratio 6:1.

Figure 3 shows three examples of how the symmetrical body can be designed. The body shown in Figure 3a is a
35 circular paraboloid and is constructed of homogenous metallic material. The body according to Figure 3b is a hollow conical shape with a cavity 6 surrounded by a metallic casing 7. A third more varied shape is shown

WO 2004/006388

PCT/SE2003/001098

7

in Figure 3c. The body is shown here homogeneous, but can also be constructed with a cavity. In a more extreme embodiment, the body can even be shaped so that it does not taper continuously, but can have a flaring midsection. The metallic material can consist of aluminium, stainless steel or other suitable conductive metallic material. The symmetrical bodies of the antenna elements covered with metallic material constitute the radiating elements of the antenna.

10

As shown best in Figure 1, a screw connection 8 is arranged to connect the rotationally-symmetrical body 4 to the earth plane 2. In the example shown, the screw connection consists of a projecting threaded pin 9 permanently attached to the rotationally-symmetrical body or alternatively constructed in one piece with the body. The threaded pin 9 engages with a threaded hole 10 formed in the earth plane 2. A spacing sleeve 11, see Figure 4, is arranged between the rotationally-symmetrical body 4 and the earth plane 2. The spacing sleeve 11 is provided with two cable bushes 12 and 13 with an opening 14 in the radial direction of the spacing sleeve and an opening 15 in the axial direction. In the centre of the spacing sleeve, there is a hole 16 dimensioned to take the pin 9. In addition to the hole 16, the spacing sleeve is provided with two further holes 23, 24 to engage with pins 25, 26 projecting from the earth plane 2.

For installing an antenna element, the spacing sleeve 11 is put in place centrally over the threaded hole 10. In addition, the requisite cables 17 are put in place. Thereafter, the rotationally-symmetrical body 4 with the threaded pin 9 is screwed tight onto the earth plane 2 with the spacing sleeve between. The spacing sleeve 11 is held fixed relative to the earth plane 2 while the body 4 is screwed tight. At a suitable moment, the screwing movement is discontinued. As the

WO 2004/006388

PCT/SE2003/001098

8

body 4 is rotationally symmetrical, the rotational position of the body has no effect on the function of the antenna. In the embodiment shown here, the spacing sleeve 11 is fixed relative to the earth plane 2 by the interaction between the projecting pins 25, 26 on the earth plate and holes 23, 24 in the spacing sleeve 11. Other solutions are possible within the framework of the invention.

Slots 21, 22 are arranged in the earth plane 2. In combination, these slots form channels around each antenna element 3. In the example shown in Figure 2, the channel network is constructed of five parallel slots 22 that are intersected at right angles by five parallel slots 21. The electrical function of the slots is to act as an open circuit.

As indicated by broken lines in Figure 1, a feeder unit is arranged in association with the underside of the earth plane 2. The feeder unit has been given the reference numeral 18 and can consist of a plurality of microwave units 19, 20, each of which serves a plurality of antenna elements via cables 17. By arranging the microwave units directly in contact with the earth plane 2, the simplest possible connection of the antenna units 3 is obtained with short cable runs and few or no joints. It is also possible to design the feeder unit consisting of microwave units in such a way that the microwave units form the earth plane 2 of the group antenna.

The group antenna is suitable for modular construction and, in the embodiment described above, comprises two modules 27 and 28. A broken line 29 marks the interface between the modules 27 and 28. When the group antenna is constructed of adjacent modules in this way, with each module comprising a number of antenna elements 3, a joint is needed between adjacent modules. This joint

WO 2004/006388

PCT/SE2003/001098

9

is located suitably centrally in a slot, and in Figures 1 and 2 is located in one of the slots 21 according to the broken line 29. A location of the joint centrally in a slot is favourable as the electrical surface
5 currents are weak at the bottom of the slot. By this means, no strong current paths are cut.

The invention is not limited to the embodiments described above as examples, but can be modified within
10 the framework of the following patent claims.

WO 2004/006388

PCT/SE2003/001098

10

Claims

1. Electrically controlled broadband group antenna comprising a plurality of antenna elements arranged in a common plane and connected to a feeder unit, characterized in that each antenna element comprises a rotationally-symmetrical body arranged on an earth plane that is common to several antenna elements, with the axis of rotation of the body essentially perpendicular to the earth plane, which body, at the end furthest away from the earth plane, is shaped so that it tapers inwards with increasing distance from the earth plane and is provided with a metallic casing surface.
2. Group antenna according to Claim 1, characterized in that the earth plane is provided with recesses in the forms of slots that separate the antenna elements from each other and function electrically as open circuits.
3. Group antenna according to any one of the preceding claims, characterized in that the antenna elements are connected to the earth plane by means of a connection that can be broken, such as a screw connection.
4. Group antenna according to any one of the preceding claims, characterized in that a spacing sleeve is incorporated in each antenna element at the transition between the rotationally-symmetrical body and the earth plane.
5. Group antenna according to any one of the preceding claims, characterized in that the earth plane is provided with two cable bushes for each antenna element, which are each allocated a double-conductor, for example a coaxial cable, one conductor of which is

WO 2004/006388

PCT/SE2003/001098

11

attached to the antenna element and the other conductor of which is attached to an adjacent antenna element.

5 6. Group antenna according to any one of the preceding claims, characterized in that the antenna elements are placed in a rectangular grid.

10 7. Group antenna according to any one of Claims 1-5, characterized in that the antenna elements are placed in a triangular grid.

15 8. Group antenna according to Claims 4 and 5, characterized in that the spacing sleeves comprise cable bushes.

20 9. Group antenna according to any one of the preceding claims, characterized in that two adjacent antenna elements are arranged with a distance between centres of essentially half a wavelength for the highest working frequency of the group antenna.

25 10. Group antenna according to any one of the preceding claims, characterized in that the feeder unit comprises one or more microwave units that form the antenna elements' common earth plane.

30 11. Antenna element suitable for incorporation in an electrically controlled broadband group antenna according to any one of the preceding claims, the antenna element comprising a rotationally-symmetrical body tapering towards one end, characterized in that the rotationally-symmetrical body is provided with a metallic casing surface.

35 12. Antenna element according to Claim 11, characterized in that the other end of the body comprises means for attaching the body in such a way that it can be removed.

WO 2004/006388

PCT/SE2003/001098

12

13. Antenna element according to Claim 12,
characterized in that the means for attaching the body
in such a way that it can be removed comprise one part
5 of a screw connection.

14. Antenna element according to any one of the
preceding Claims 11-13, characterized in that
rotationally-symmetrical body is essentially a conical
10 shape.

15. Antenna element according to any one of Claims 11-
13, characterized in that rotationally-symmetrical body
is essentially a circular paraboloid.

16. Antenna element according to any one of Claims 11-
15, characterized in that the rotationally-symmetrical
body consists principally of aluminium.

20 17. Antenna element according to any one of Claims 11-
16, characterized in that the rotationally-symmetrical
body is hollow.

25 18. Antenna element according to any one of Claims 11-
16, characterized in that the rotationally-symmetrical
body consists of an homogenous metallic material.

30 19. Antenna element according to any one of Claims 11-
18, characterized in that a circular spacing sleeve is
incorporated in association with the other end of the
body.

35 20. Antenna element according to Claim 19,
characterized in that the spacing sleeve is provided
with at least one cable bush with a first opening
aligned in the radial direction of the spacing sleeve
and a second opening aligned parallel with the axis of
symmetry of the body and the sleeve.

WO 2004/006388

PCT/SE2003/001098

13

21. Antenna module comprising a plurality of antenna elements according to any one of Claims 11-20.

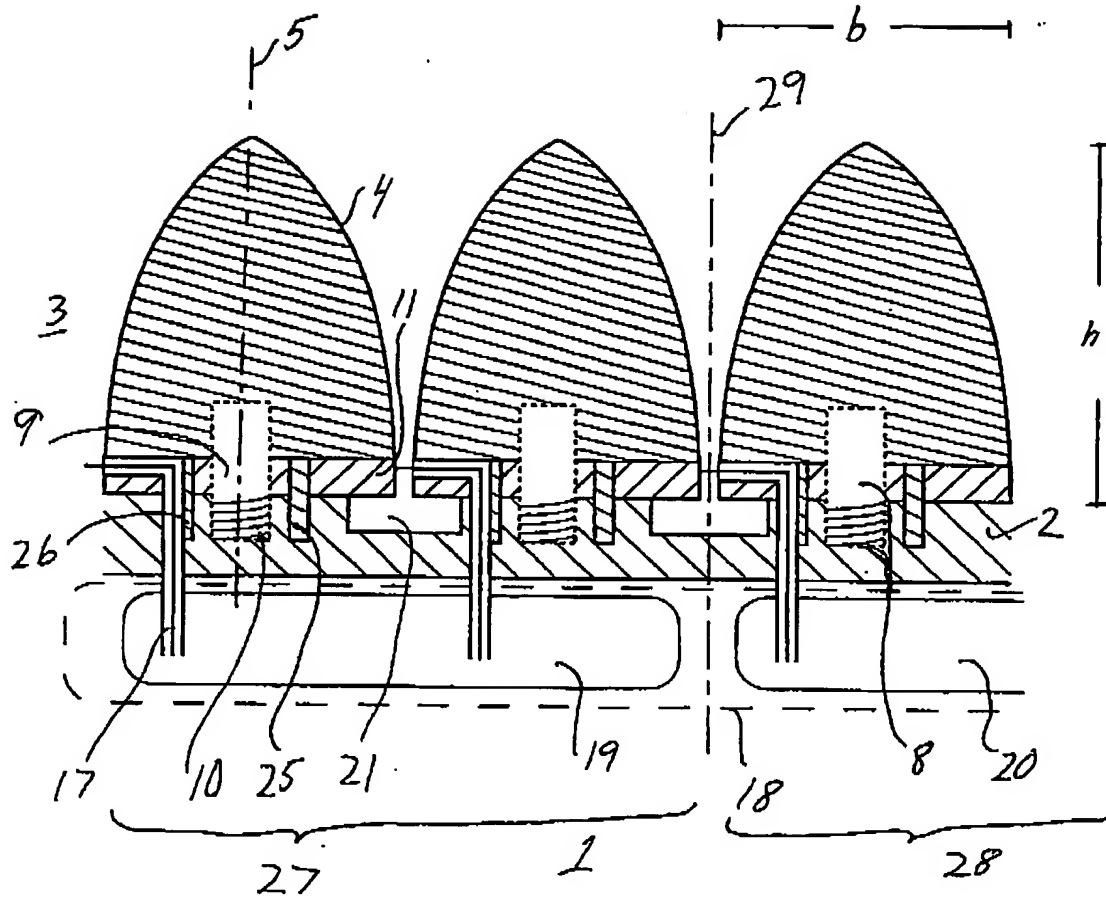


Fig 1

10/520 462

WO 2004/006388

PCT/SE2003/001098

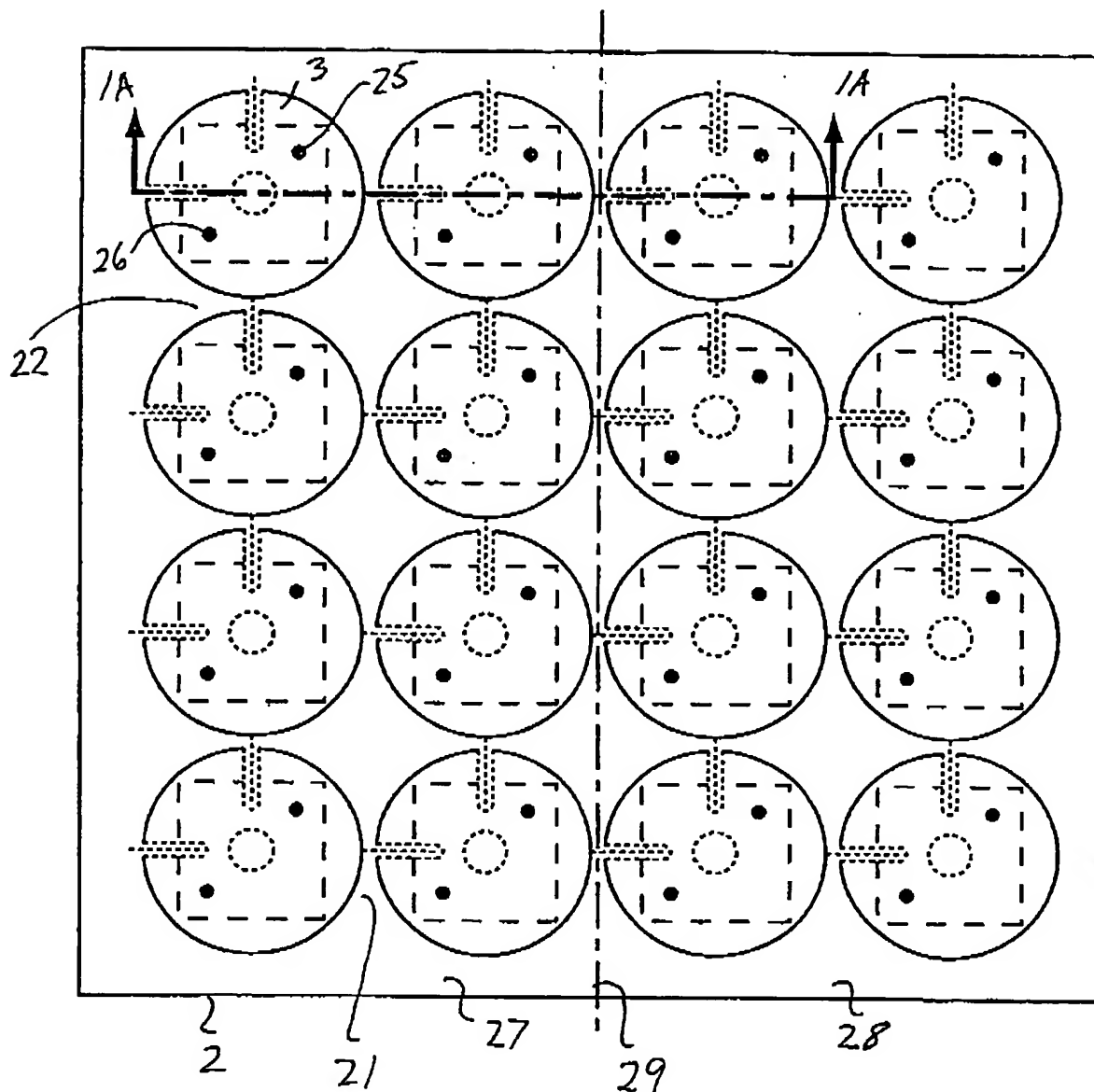


Fig. 2

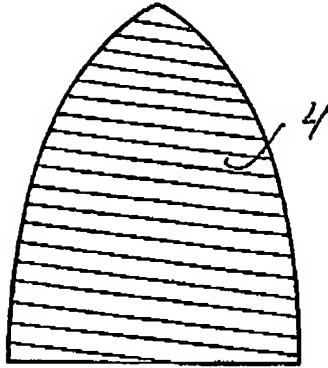


Fig. 3a

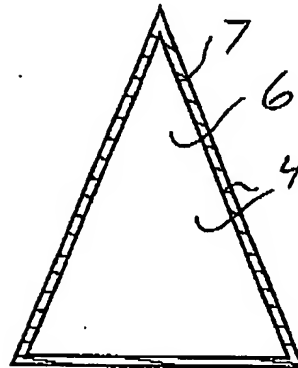


Fig. 3b

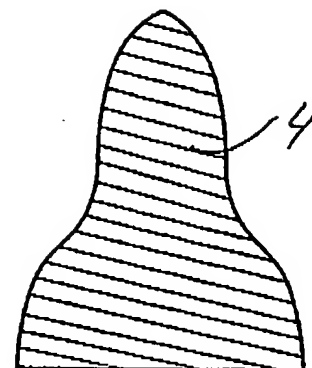


Fig. 3c

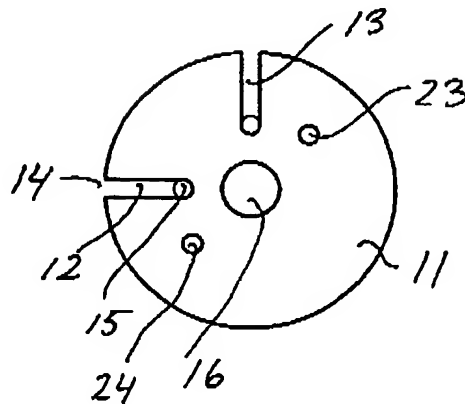


Fig. 4

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☒ FADED TEXT OR DRAWING
- ☒ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☐ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.